Quarterly Progress Report

Project No. DE-FC26-05NT42304

Lovelace Biomedical and Environmental Research Institute
Albuquerque, NM

Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions

Quarter 2

May 1, 2005 – July 31, 2005

Project Director:

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Contents

1. Executive Summary

This Report describes progress during the second calendar quarter of project DE-FC26-05NT42304 “Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions”. The project was initiated on February 3, 2005. The first quarterly report described progress through April 2005. This report describes progress through July 2005.

The purpose of this project is to conduct a comprehensive laboratory-based evaluation of selected respiratory and cardiac health hazards of repeated, subchronic (up to 6 months) inhalation of simulated key components of “downwind” emissions of coal combustion. This project is being performed as an integral part of a joint government-industry program termed the “National Environmental Respiratory Center” (NERC), which is aimed at disentangling the roles of different physical-chemical air pollutants and their sources in the health effects associated statistically with air pollution. The characterization of the exposure atmosphere and the health assays will be identical to those employed in the NERC protocols used to evaluate other pollution source emissions.

The project has two phases, each encompassing multiple tasks. Guidelines for the composition of the exposure atmosphere were set by consensus of an expert workshop. The capability to generate the exposure atmosphere, and pilot studies of the comparative exposure composition using two coal types, will be accomplished in Phase 1. In Phase 2, the toxicological study will be conducted using one of the coal types tested in Phase 1. This project provides 50 % support for the work in Phase 1 and 20% support for the work in Phase 2.

During this reporting period (May-July, 2005), the project was in Phase 1, Task 1, and progressed satisfactorily according to the overall schedule. The sequence of certain of the subtasks has differed from the original estimate, as opportunities for progress from week to week have shifted from subtask to subtask, but the project is not only at its planned stage, but has also made advance progress on certain tasks planned for later completion. Technical and logistic challenges are being met, and no serious obstructing issues or problems have arisen. We are still estimating that the project will continue as scheduled.

Work during the reporting period focused on three subtasks: 1) completing the assembly of the generation system in preparation for generating coal emissions; 2) resolving personnel allocations for refining the system and conducting the generation trials and exposures; and 3) obtaining the coals to be used in preliminary trials beginning in September. Progress on these subtasks is summarized below:

- The construction of the generation system was completed in an initial configuration. We are now ready to begin burning coal.
- A newly-recruited doctoral-level aerosol scientist was assigned to manage the daily operation of the laboratory.
- Arrangements were completed for UND/EERC to receive and process shipments of two coal types.

In addition, advantage was taken of the availability of technical personnel to assemble the dilution/distribution and exposure system, a subtask under Phase 2, Task 1 originally scheduled for May-June 2006.

2. Results of Work During Reporting Period

a. Approach

The general approach taken in this project has not changed from that described in the application. The approach to Phase1, Task 1, involves: 1) collecting information on the use of drop-tube furnaces for laboratory-scale coal combustion; 2) collecting information on potential coal types and resources for obtaining coal and processing it for use in the laboratory; 3) finalizing a design for the drop-tube furnaces to be used in this project; obtaining processed coal; 4) obtaining, installing and testing the furnaces; 5) developing and testing the coal aerosol generator; 6) assembling the emissions generation/modification system; and 7) confirming system operation by generating coal emissions. The work will then proceed to Phase 1, Task 2: conducting iterative generation trials with PRB coal in an attempt to meet the target ratios of particulate and non-particulate components at target total particle mass concentrations.

The last progress report described the accomplishment of items 1 through 5 above. Work during this reporting period focused largely on completing item 6. In addition, progress was made on allocating the staffing necessary to proceed in a timely manner, and acquiring the larger amounts of two test coals necessary to complete the generation trials and exposures. Moreover, we took advantage of the temporary availability of additional technical manpower to assemble the systems for diluting and distributing the different concentrations and exposing animals well ahead of schedule. This work was described in the application under Phase 2, Task 1, subtask 1 and scheduled for May-June 2006. Thus, not only is the project on schedule overall, but some portions are ahead of schedule.

1) Assembly of Generation/Mixing and Exposure Systems

The last quarterly report described the assembly and preliminary testing of a prototype coal dust aerosol generator, and the installation of the two electric furnaces and their electrical supplies. The remainder of the generation system, including second-generation aerosol generators, has now been constructed.

Separate, identical aerosol generators are mounted next to each of the two identical furnaces. The effluents from the furnaces are routed through heat exchangers and into a buffer chamber, constructed from steel drums. In parallel, the effluent from a sulfate generator is routed to a second buffer chamber constructed from a steel drum. The flows exiting the two buffer chambers are routed to a “T’ fitting in which the two flows (coal emissions and sulfate) are mixed and then introduced into the bottom of the mixing/aging chamber. With the exception of the steel buffer chambers, all materials are stainless steel. Provision is made for dilution and extraction of excess diluted material at several points, including the two flow paths for the coal emissions and sulfate, and the combined flow. The mixing chamber consists of a 1.0 m^3 stainless steel animal exposure chamber with windows for observation, a large door for cleaning, and multiple sampling ports. The effluent is routed from the top of the mixing chamber through the wall and into the distribution plenum in the adjacent exposure room.

The coal emissions generation portion of the system is shown below in Figure 1. The pulverized coal is aerosolized by passing a stream of air over the surface of dust contained in a reservoir tube [A]. The outflow from the reservoir tube is routed through an exit capillary tube maintained at a constant distance from the surface of the coal a screw-driven mechanism (standard laboratory syringe pump). Flow through the aerosol generator is controlled by a rotameter [B]. The aerosol is routed to the top of the electric furnace [C].

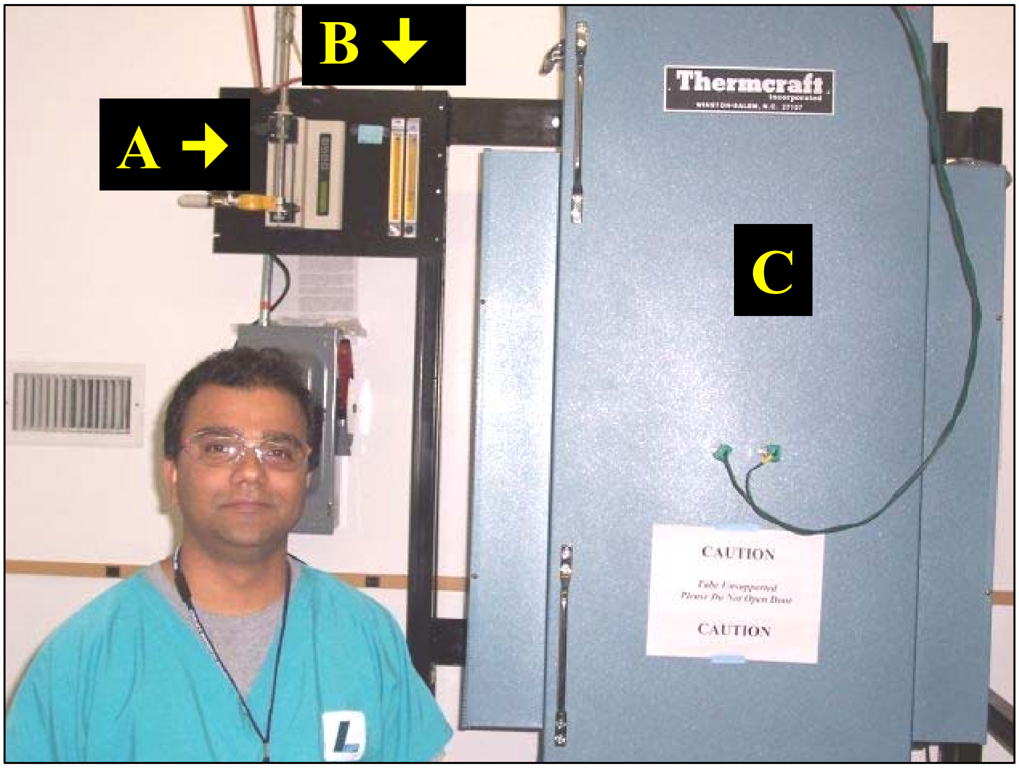

Figure 1. Coal aerosol generator, furnace, and Dr. Misra

The above photo also shows Dr. Chandan Misra, a recently-recruited aerosol scientist who now has primary responsibility for the day-to-day development of the exposure atmospheres and operation of the exposure system throughout the project. Dr. Misra reports to Dr. McDonald, who has general oversight of the exposure portions of the project. Dr. Misra's addition to the staff will greatly facilitate progress from this point forward, by ensuring the dedicated oversight of technical staff and coordination of all activities associated with development of the system. His curriculum vitae is attached to this report as Appendix A.

Additional components of the system are shown in Figure 2. The two coal aerosol generators and furnaces can be seen in the background. In the foreground are the two steel drums comprising the buffer chambers for the coal emissions [A] and sulfate aerosol [B]. in the center is the control panel for the several dilution/dump points at which flows are diluted and excess is dumped [C]. The control portions of the heat exchangers for furnace effluent are also visible [D]. Seen upper center background of this view, is the flow path exiting the top of the mixing/aging chamber and splitting into tubing leading into the adjacent room or exhausting excess material to a waste stream [E]. In this perspective, the tubing appears to be exiting the top of the control panel in the foreground, but is actually exiting the chamber partially visible behind the control panel.

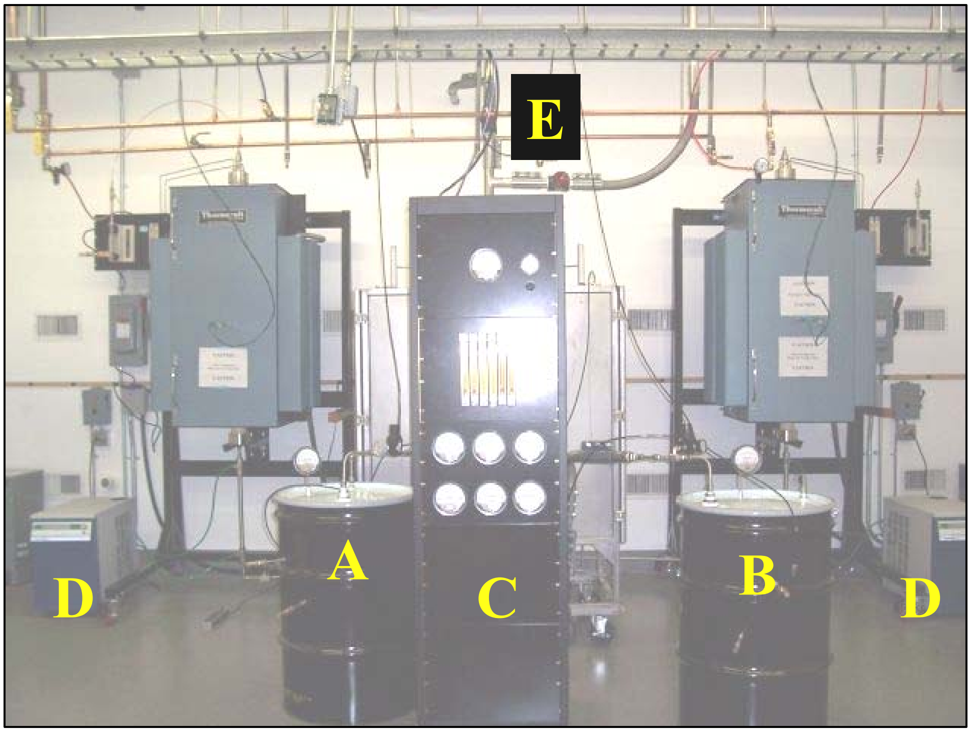

Figure 2. Front view of the generation system

The view in Figure 3 shows portions of the system hidden behind the control panel in Figure 2. The 2-inch stainless steel pathways from the coal emissions buffer chamber [A] and the sulfate buffer chamber [B] are merged at a "T" fitting [C] before passing into the mixing/aging chamber [D]. The mixing/aging chamber is a 1.0 m^3 animal exposure chamber with the shelving and caging removed. The front and rear doors of the chamber provide excellent visualization of the contents, ready access for cleaning, and multiple ports for sampling. Flow to the exposure suite in the adjacent room exits the chamber at the top [E], with provision for dumping excess flow to a waste line.

Figure 4 shows a portion of the dilution/distribution system in the exposure room. Flow from the top of the mixing/aging chamber in the adjacent generation room passes into a horizontal distribution plenum [A], which has waste exits at both ends to ensure good distribution among the four exits leading to exposure chambers containing each of the four concentrations (parallel dilutions) of the exposure atmosphere. One of the tubes leaving the distribution plenum for an exposure chamber is visible [B]. Tops of three of the exposure chambers appear in this view [C]. Each exposure chamber has a monitoring panel with gauges and instruments for monitoring flows, pressures, and humidity [D].

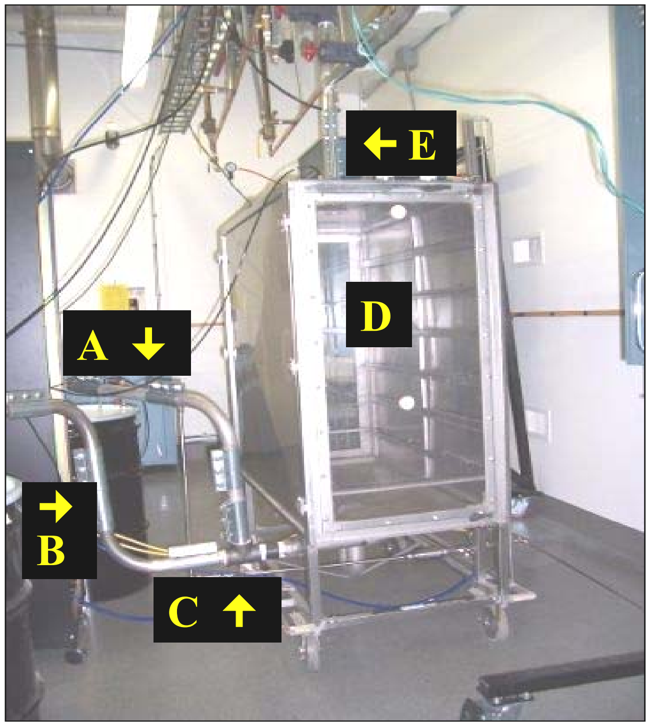

Figure 3. Flows from coal emissions and sulfate aerosol buffer chambers merging before entry into the mixing/aging chamber

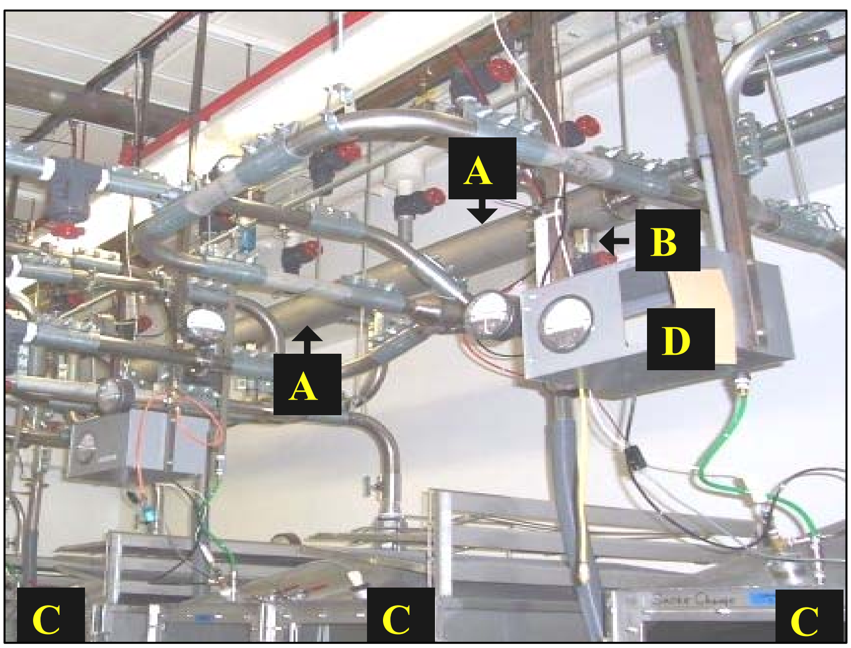

Figure 4. Dilution/distribution system in exposure room

The exposure system is shown more fully in figure 5. The four chambers for exposing animals to the four dilutions of the test atmosphere can be seen. A fifth chamber for exposing controls to clean air is at the rear of the viewer on the opposite wall. The exposure atmosphere enters the chambers at the top [A] and exits to waste exhaust from the bottom of the chambers via flexible tubing [B].

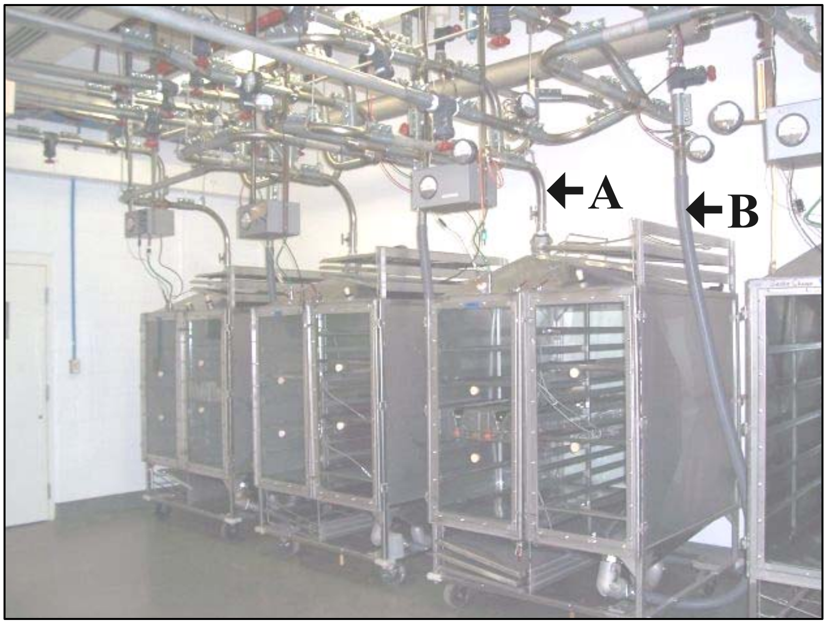

Figure 5. Animal exposure chambers

In addition to assembly of the system components described above, additional work was accomplished during this reporting period in preparation for the initial coal burning trials. Electrical power supplies were re-wired to accommodate the two heat exchangers necessary to quench the emissions after exiting the furnaces. The sulfate generator components were procured, and were partially assembled. Instruments for monitoring sulfur dioxide and sulfate were procured and calibrated. Wiring was run in the exposure room for monitors and controls. The furnaces were brought to temperature to burn out residue that always accompanies new ceramic combustion tubes. Overall, the system was brought to the point that we are ready to begin burning coal and passing emissions through the system.

2) Staffing

An important part of the effort accomplished during this reporting period was the resolution of the personnel allocations necessary to conduct the generation trials and exposures after the system was assembled. The project was able to progress on schedule to this point because it consisted largely of specifying, procuring, and assembling system components, as described above. Dr. McDonald provided direct oversight of this effort, and has moved work along largely through the availability of senior technical staff “borrowed” from other programs at the Institute. Successfully accomplishing the more technicallychallenging and labor-intensive generation trials from this point forward requires professional and technical manpower that can be dedicated consistently to the effort.

One key issue was the assignment of an individual having suitable credentials for assuming the daily professional guidance of the effort, under Dr. McDonald's general oversight. Recruitment to enlarge the Institute's professional aerosol science staff resulted in the availability of an individual especially well-suited to fill this role. As described above under Figure 1, Dr. Chandan Misra has assumed this role. After training in chemistry, Dr. Misra obtained his doctorate in the very active environmental aerosol and chemistry group at the University of California, Los Angeles. His thesis work on assessment of the physical, chemical, and toxicological characteristic of ambient particles provided both excellent graduate training, and experience quite relevant to the needs of this project. His postgraduate experience in the field of aerosol measurement technologies provided further relevant experience. His credentials are detailed in Appendix A. Drawing on our adequate pool of well-trained aerosol and exposure technical staff, Dr. Misra is now undertaking the generation of coal emissions, using the PRB coal already in hand.

3) Procurement of Test Lots of Coals

Decisions regarding the sources for the two coal types to be used were described in the last report. During this reporting period, procurement actions, inter-institutional agreements, and logistics were put into place to obtain coals from the Black Thunder Mine in Campbell County, Wyoming (Powder River Basin [PRB] coal) and the Jones Fork blending/processing plant in Knott County, Kentucky (Central Appalachian Low Sulfur [CALS] coal). Those coals are being obtained at the sources as this report is written, and will be shipped to UND/EERC for grinding, mixing, partial analysis, packaging under nitrogen, and shipping to LRRI.

During the last reporting period, we obtained processed PRB coal from the same source (Black Thunder Mine, via UND/EERC) from the EPA laboratory in North Carolina. Because the generation trials were planned to begin with PRB coal, the initial system shake-down and range-finding generation trials will use the EPA-source coal. This strategy was adopted to ensure that obtaining the actual study coals was not a limiting factor on progress on developing the coal aerosol generator and conducting the initial combustion trials. Our generation trials will have switched to the actual study coal before the end of the next reporting period.

b. Results and Discussion

Other than the progress described above, there are no specific technical results or data to report during this quarter. The project will produce preliminary results during the next quarter from the initial combustion trials.

c. Conclusions

The project continues to appear technically feasible and should progress as planned and according to schedule. We are on track on the overall schedule, although the sequence of accomplishing some of the subtasks has varied to take advantage of resources and opportunities as they are available. For example, the animal exposure system is constructed approximately a year ahead of schedule. This will be very useful, because it will allow the generation trials to determine the composition and component ratios in the actual exposure chambers at the final exposure concentrations, rather than just at the outlet of the mixing chamber.

3. Milestones

The only milestone pertinent to this reporting period is Phase 1, Task 1 "Assemble Drop-Tube Furnace and Emissions Modification System". That milestone was to be completed in August 2005, and it has been completed.

Phase 1, Task 2 "Conduct Iterative Generation/Modification Trials Using PRB Coal", is scheduled to begin in August 2005. The work under that milestone is being initiated on schedule, and there are no issues that should prevent completion of that milestone on time.

4. Cost and Schedule Status

a. Cost Status

DOE expenses as of 7/31/05:	$ 89,210.94
LRRI cost share as of 7/31/05:	$ 17,840.39
Other cost share as of 7/31/05:	$ 71,361.55
Total expenditures as of 7/31/05:	$178,403.88

b. Schedule Status

The project is on schedule. Expenditures will increase during the next reporting period as costs for coal procurement and processing will be expensed and combustion trials will be underway on nearly a daily basis.

5. Significant Accomplishments

Significant accomplishments were described in detail above. In summary, we have:

- Assembled the generation/modification system
- Resolved staffing assignments
- Finalized arrangements for obtaining two study coals
- Assembled the animal exposure system (well in advance of schedule)

6. Problems, Delays, and Corrective Actions

We have not encountered any problems or delays that have obstructed progress significantly. One challenge was the assignment of personnel for the generation trials. That was accomplished as described above. No other corrective actions have been necessary.

7. Technology Transfer Activities

There have been no technology transfer activities or issues to date. It is not anticipated that this project will generate any intellectual property or technical advances that will raise technology transfer issues. The product of this project is explicitly information on the health effects of exposure to modified coal emissions, and that information is to be communicated to the scientific community, public, and other stakeholders through peer-reviewed, open literature publications.

APPENDIX A

The Curriculum Vitae for Dr. Chandan Misra is attached as and appendix to this report.

CHANDAN MISRA, Ph.D.
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SUMMARY

Strong technical background in Aerosol Science and Engineering, Aerosol Sampling Technologies and Environmental Engineering. Extensive research experience in health effects studies, funded by the Southern California Particle Center and Supersite, combining aerosol expertise with toxicology.

EXPERIENCE

Current
July 2005-

Associate Research Scientist (Aerosol Engineer)
Lovelace Respiratory Research Institute
Albuquerque, NM

Working as an Associate Research Scientist in the Aerosol and Chemistry group at LRRI. The job involves working in multi-disciplinary scientific teams to develop aerosol inhalation exposure systems for research programs in environmental safety evaluation of aerosols (including diesel emissions, tobacco smoke etc.), bioaerosols, and pharmaceutical test agents. Characterizing aerosol exposure systems using a number of high-tech instruments including FMPS^{TM}, APS and DustTrak^{TM} aerosol monitors. Supervising various technicians and giving them direction for fabrication and operation of the inhalation exposure systems. Also responsible for writing protocols, participating in aerosol development and coordinating study activities at LRRI.

February 2005-
June 2005

Research Associate
School of Public Health
University of Minnesota

Worked as a Research Associate (*pro bono*) in School of Public Health at the University of Minnesota. Involved in exposure assessment studies using TSI's DustTrak^{TM} aerosol monitors.

September 2003-
February 2005

Aerosol Scientist
Salter Labs
Arvin, CA

Worked as an Aerosol Scientist at Salter Labs. Primary job function encompassed development, testing and validation of variety of high-tech medical devices, including aerosol drug delivery systems, nebulizers and inhalers.

EDUCATION

July 2000-
August 2003

Research Assistant, Civil and Environmental Engineering
University of Southern California
Los Angeles, CA
<u>Thesis</u>: Technologies for Assessment of Physical, Chemical and Toxicological Characteristics of Ambient Ultrafine Particles
Earned Ph.D. in Environmental Engineering. Developed 3 new aerosol monitoring instruments. A continuous coarse particle monitor (CCPM) for measuring ambient coarse particle (2.5-10 μm) concentration. Patent filed for the developed monitor. This monitor will be commercially available in near future to be marketed by R& P Co. Inc. (now part of the Thermo Electron Corporation). Developed and fully characterized a PM_{10} impaction inlet for the CCPM. Also developed a personal cascade impactor sampler (PCIS) for size segregated personal level sampling of ambient particulate. The PCIS collects particles in 5 size bins based on particle aerodynamic diameter. Patent filed for PCIS. PCIS is now available commercially from SKC Inc., Eighty Four, PA under the brand name of Sioutas Cascade Impactor™ (http://www.skcinc.com/prod/225-370.asp). Developed and evaluated a high volume ultrafine impactor to remove particles above 0.15 μm in aerodynamic diameter. The developed impactor can be used for collecting bulk samples of ultrafine particulate (d_a<0.15 μm). The impactor will also be used to remove accumulation mode (d_a > 0.15 μm) particles in order to perform human exposure to ultrafine particles. Performed the size segregated sampling of ultrafine particles and studied chemical characteristics of these particles and for the first time documented it in the literature. Besides, worked on particle concentrator to concentrate coarse, fine and ultrafine particles used for *in-vitro* as well as *in-vivo* studies. Part of the team that performed real time exposure of humans to concentrated fine and coarse particles using particle concentrators at the Los Amigos Rehabilitation and Educational Institute, Downey, CA. Studied toxic effects of ultrafine particles on cells and developed the human ultrafine particle exposure facility to expose humans for the first time to concentrated real-world ultrafine particles.

July 2000-
May 2002

Research Assistant, Civil and Environmental Engineering
University of Southern California
Los Angeles, CA
Earned Masters in Science (MS) in Environmental Engineering with emphasis on air pollution. Took advanced courses including air pollution control technologies, risk assessment, atmospheric chemistry and applied air quality management.

July 1998- Jan 2000	*Teaching Assistant, Center for Environmental Science and Engineering,* *Indian Institute of Technology-Bombay, INDIA* <u>*Dissertation*</u>*: A Hybrid Reactor for Priority Pollutant-Trichloroethylene Removal.* Earned Masters in Technology (M. Tech.) in Environmental Science and Engineering. The program provided a solid foundation and understanding of various concepts of Environmental Engineering. Teaching assistant for courses on Environmental Chemistry and Environmental Monitoring Lab. Worked actively on a hybrid biological reactor to remove trichloroethylene from wastewater. Also worked on various EIA projects and did air sampling at various locations in Mumbai using high volume TSP and cascade impactors.
July 1995- Jun 1997	*Student, Department of Chemistry* *University of Delhi* *Delhi, INDIA* Earned Masters in Science (M. Sc.) in Chemistry with specialization in Organic Chemistry. Learned advanced inorganic and physical chemistry Gained valuable expertise in various aspects of advanced organic chemistry.
July 1992- Jun 1995	*Student, Department of Chemistry* *Hindu College, University of Delhi* *Delhi, INDIA* Earned Bachelors in Science with Honors (B. Sc. Hons) in Chemistry. The program provided a firm grounding in inorganic, organic and physical chemistry.
PUBLICATIONS	12 papers in peer reviewed journals. 10 conference presentations.
SKILLS	UNIX, Technical Communication (Word, Excel, PowerPoint).
AFFILIATIONS:	Member, American Association for Aerosol Research Member, American Association for Respiratory Care Member, International Society for Aerosols in Medicine

PUBLICATIONS

1. Zhao, Y., Bein, K. J., Wexler, A. S., **Misra, C.**, Fine, P. M., Sioutas, C. (2005). Field evaluation of the versatile aerosol concentration enrichment system (VACES) particle concentrator coupled to the rapid single-particle mass spectrometer (RSMS-3). Journal of Geophysical Research. 110: D07S02
2. Khlystov, A., Zhang, Q., Jimenez, J.L., Stanier, C., Pandis, S., Canagaratna, M.R., Fine, P.M., **Misra, C.**, Sioutas, C. (2005) In situ concentration of semi-volatile aerosol using water-condensation technology**.** Journal of Aerosol Science. 36: 866-880
3. Campbell, A., Oldham, M., Becaria, A., Bondy, S.C., Meacher, D., Sioutas, C., **Misra, C.**, Mendez, L.B., Kleinman, M.T. (2005). Particulate matter in polluted air may increase biomarkers of inflammation in mouse brain. Neurotoxicology. 26: 133-140
4. Singh, M., **Misra, C.**, Sioutas, C. (2003) Field evaluation of a personal cascade impactor sampler. Atmospheric Environment. 37 (34) 4781-4793
5. **Misra, C.**, Fine, P.M., Singh, M. Sioutas, C. (2003) Development and evaluation of a compact facility for exposing humans to concentrated ambient ultrafine particles. Aerosol Science and Technology. 38: 27-35
6. Li, N., Sioutas, C., Cho, A., Schmitz, D., **Misra, C.**, Sempf, J., Wang, M., Oberley, T., Froines J., Nel, A. (2003) Ultrafine particulate pollutants induce oxidative stress and mitochondrial damage. Environmental Health Perspectives. 111: 455-460
7. **Misra, C.**, Geller, M.D., Sioutas, C., Solomon, P. (2003). Development and evaluation of a PM_{10} impactor inlet for the continuous coarse particle monitor. Aerosol Science and Technology. 37:271-281
8. **Misra, C.**, Kim, S. Shen, S., Sioutas, C. (2002). A high flow rate, low pressure drop impactor for inertial separation of ultrafine from accumulation mode particles. Journal of Aerosol Science. 33: 735-752
9. **Misra, C.**, Singh, M., Shen, S., Sioutas, C., Hall, P.M. (2002). Development and evaluation of a personal cascade impactor sampler (PCIS). Journal of Aerosol Science. 33:1027-1047
10. Geller, M.D., Kim, S., **Misra, C.**, Sioutas, C., Olson, B.A., Marple, V.A. (2002). A methodology for measuring size-dependent chemical composition of ultrafine particles. Aerosol Science and Technology. 36:748-762
11. **Misra, C.**, Geller, M.D., Shah, P., Sioutas, C., Solomon, P. (2001). Development and evaluation of a continuous coarse (PM_{10}-$PM_{2.5}$) particle monitor. Journal of Air and Waste Management. 51: 1309-1317
12. **Misra, C.**, Gupta S.K. (2001). A hybrid reactor for priority pollutant-trichloroethylene removal. Water Research. 35 (1): 160-166

CONFERENCE PRESENTATIONS

1. 2004 Annual Conference of the American Association for Aerosol Research, Atlanta, GA October 2004. In-situ concentration of semi-volatile aerosol using water condensation technology. (Khlystov, A., Zhang, O., Jimenez, J.L., Stanier, C., Pandis, S., Canagaratna, M.R., Fine, P.M., Misra, C., Sioutas, C)
2. 2003 Annual Conference of the American Association for Aerosol Research, Anaheim, CA October 2003 Development and evaluation of a compact facility for exposing humans to concentrated ambient ultrafine particles (Misra, C., Fine, P.M., Singh, M. Sioutas, C.)
3. 2003 American Association for Aerosol Research PM Meeting, Pittsburgh, PA April 2003 Exposure to concentrated fine and ultrafine ambient particles near heavily trafficked roads induces allergic reactions in mice (Kleinman, M.T., Meacher, D., Oldham, M., Sioutas, C., Misra, C., Cho, A., Froines, J.)
4. 2003 American Association for Aerosol Research PM Meeting, Pittsburgh, PA April 2003. Fine and coarse particles of the California central valley differentially induce adverse effects in the lungs of rats. (Smith, K.R., Kim, S., Misra, C., Recendez, J.J., Aust, A.E., Sioutas, C., Pinkerton, K.E.)
5. 2003 American Association for Aerosol Research PM Meeting, Pittsburgh, PA April 2003. Using ultrafine concentrators to increase the hit rate of single particle mass spectrometers. (Zhao, Y., Bein, K.J., Wexler, A.S., Misra, C., Fine, P.M., Sioutas, C.)
6. 2003 American Association for Aerosol Research PM Meeting, Pittsburgh, PA April 2003 Development and evaluation of a compact facility for exposing humans to concentrated ambient ultrafine particles (Misra, C., Fine, P.M., Singh, M. Sioutas, C.)
7. 2003 American Association for Aerosol Research PM Meeting, Pittsburgh, PA April 2003. Field evaluation of a personal cascade impactor sampler (PCIS). (Singh, M., Misra, C., Sioutas, C.)
8. 2002 Annual Conference of the American Association for Aerosol Research, Charlotte, NC October 2002. A high flow rate, low pressure drop impactor for inertial separation of ultrafine from accumulation mode particles (Misra, C., Sioutas C.)
9. 2002 Annual Conference of the American Association for Aerosol Research, Charlotte, NC October 2002. Development and evaluation of a personal cascade impactor sampler (PCIS). (Misra, C., Singh, M., Sioutas, C.)
10. 2001 Annual Conference of the American Association for Aerosol Research, Portland, OR October 2001. Development and evaluation of a continuous coarse (PM_{10}-$PM_{2.5}$) particle monitor. (Misra, C., Geller, M.D., Sioutas, C.)